International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Intermittent Computing for Sustainable Agriculture

Device Design and Applications in Low - Energy Environments

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Abstract: ***Contemporary agriculture is increasingly transitioning from traditional energy sources, like fossil fuels and radioactive elements, to renewable energy sources such as solar, wind, hydroelectric, and biomass energy. This shift is driven by the need to mitigate environmental impact and meet the demands of rapid climate change and overpopulation. Renewable energy sources are regenerative, environmentally friendly, and cost - effective. The agriculture sector, especially in India, holds significant potential for green energy transformation, with solar energy being particularly accessible. Technological advancements are essential for this transition, with innovations such as photovoltaic systems, wind turbines, and advanced mechanized farming equipment playing crucial roles. India, with its rich agricultural heritage and current status as a leading producer of various crops, continues to innovate in sustainable practices and technologies, aiming to further reduce environmental impact and improve efficiency. This paper explores the challenges and motivations behind the development of cleaner, more energy - efficient technologies in agriculture and provides recommendations for future advancements.***

Keywords: renewable energy, agriculture, sustainable practices, technological advancements

1. Introduction

From traditional to renewable sources, contemporary agriculture has witnessed a significant shift in the use of energy. Traditional or conventional energy is derived primarily from two sources: fossil fuels such as coal, petroleum, or natural gas; and radioactive elements such as Thorium and Uranium. They have been in use for a long period of time. The key drawback to traditional energy is the fact that it is non - renewable. It takes millions of years to form, and cannot be replaced once used (Srestha, Mustafa, Htike, You & Kakinaka, 2022). Apart from this, it also causes great environmental impact such as air, soil and water degradation. Hence, there has been a surge in an alternative source of energy that overcomes these drawbacks: renewable energy is regenerative and environmentally friendly as it is derived from naturally occurring sources like water, wind, biofuels and sun. It does not produce greenhouse gases, is cheap, cost effective, and can be used without threat of depletion (Srestha, Mustafa, Htike, You & Kakinaka, 2022). Rapid climate change and overpopulation exert great stress on existing energy supplies hence propelling the transition to renewable energy sources.

The agriculture industry holds great potential to achieve complete green energy transformation. Solar energy is the most accessible of the available sources of clean energy. Access to solar power is available year - round in almost every part of the world. The energy produced from this source can be used to power a variety of appliances, both within and outside a household, such as solar cookers, dryers and water heaters (Sanchavat & Modi, 2020). Moreover, it can also be used in photovoltaic systems to generate electricity without any environmental pollution (Sanchavat & Modi, 2020). Wind energy is also greatly in demand and has been used from time immemorial to pump water from wells, to grind grain into flour, and even to generate electricity (Karishma, 2021). Hydroelectric power and biomass energy are also very widely used sources for generating electricity. The waste created from biomass can also be treated to be used as a sustainable organic fertiliser. All of this, however, will not be possible without the proper and considerable advancement of technology. Cutting - edge technology can help meet the growing demands of the sector in a cost and time efficient manner (Srestha, Mustafa, Htike, You & Kakinaka, 2022).

Agriculture is one of the most important sectors in India, contributing about 17% to the total gross domestic product, and providing more than 60% of the population with employment opportunities (Pandey, Soni, Sharma & Kumari, 2012). Compared to the rest of the world, India is the largest producer of pulses, milk, and jute; second largest producer of rice, wheat, sugarcane and cotton; and has the second largest cattle population, putting it at the forefront of agricultural innovation and design. It is important to note, however, that this was not always the situation. India reached their pallbearing position in the global agricultural scene only after the combined efforts of many during the Green Revolution of 1968. However, despite the revolution, the industry needs to continuously change in order to battle existing challenges, and to meet the future demands of a rapidly changing world.

This paper aims to understand the challenges and motivations towards the development of cleaner, more energy - efficient and reliable technologies within the agricultural sphere, and to provide further directions for the same.

2. Background

Started by Dr MS Swaminathan, The Green Revolution completely redesigned the traditional agricultural pattern of the country (Pandey, Soni, Sharma & Kumari, 2012). India faced a significant population growth in the 1960s, which was accompanied by a sudden, significant increase in poverty and malnourishment. At this time, agriculture was the backbone of the Indian economy, providing employment to a large portion of the population. In considering these factors, it could be seen that working for sustainable and productive agricultural practices was necessary for India to successfully move into the future. These realisations led to the Green Revolution, which aimed at making India self - sufficient in food production. Many new farming methods were employed to make this possible, the most prominent one being the use of High Yielding Varieties of seeds, especially for in -

demand crops such as wheat and rice (Evenson, McKinsey & James, 1999). These seeds were more resistant to pests and diseases and had much higher yield rates. Other processes included expansion of irrigation, mechanisation of farming, improvements in infrastructural facilities and the use of multiple cropping patterns (Evenson, McKinsey & James, 1999).

The SMAM or Sub - Mission on Agricultural Mechanisation was introduced to make high - tech farming equipment available for all farmers (Digital India, accessed July 5, 2024). Many pieces of equipment were introduced by this mission including the power tillers, rice transplanters, plant protection equipment, agricultural drones and self - propelled machinery (Digital India, accessed July 5, 2024). In a similar timeframe, NMSA (National Mission on Sustainable Agriculture) was also introduced in an effort to make agriculture more sustainable and climate resilient by adopting location - specific integrated farming systems, promoting soil health management, and making agriculture more environment - friendly by conserving natural resources and integrating efficient water management sources (Panning & Kulkarni, 2011).

In addition to the ones mentioned above, many other initiatives have been implemented, both during the Green Revolution and ever since, to increase the usage of cleaner sources of energy. SPIs (Solar Powered Irrigation Systems) have been adopted in many parts of the country. These can help to significantly reduce greenhouse gas emissions, increase access to water during dry seasons, and help provide irrigation to remote areas and areas which are not connected to the electricity grid. Solar power is also fuelling Atta Chakkis (flour mills), dryers and winnowers. Initiatives such as the KUSUM scheme aim to provide financial assistance to farmers for installing solar power plants (Panning & Kulkarni, 2011). Aside from government initiatives, private non - banking finance companies within India are also looking at bringing cleaner sources of power to rural areas. One such example is Metafin, a private, vertically integrated clean energy lender, whose one - of - a - kind financial model has allowed for better financial inclusion and for access to clean energy in the form of solar plants, to individual business - owners in rural areas across the country (Harvard Innovation Labs, 2021).

In more recent times, the agricultural sector in India has become highly mechanised. Precision farming practices are being followed, with satellite imagery and GIS (Geographic Information Systems) being used to monitor crop conditions and generate production estimates (Joshi & Varshney, 2022). The use of robots and other forms of artificial intelligence is also steadily increasing, with micro - spraying robots being used to target the spray of fertilisers directly at the base of plants and to remove weeds (Joshi & Varshney, 2022). Advanced sensors and precision technology also help these robots to efficiently pick plants. Automated irrigation systems that use IOT sensors monitor the moisture level in the soil to enable automatic watering while simultaneously reducing water wastage. These technologies have the potential to optimize agricultural yield. In addition to all these advancements made both during and beyond the Green Revolution in India, Indian policy has turned towards the betterment of agricultural industries, outside of what goes on in the fields and factories. In this way, India has historically shown itself to be resilient and forward - looking in the space of agricultural technologies.

3. Discussion

In the innovation of new technology, the majority of stakeholders within the agricultural industry, such as the innovators, the governments, and the investors may face what's called the pro - innovation bias. This is the belief that a newly developed technology would be readily accepted by society when that is generally not the case (Chadha, 2003). Similarly in agriculture, although these new technologies have the capability to drastically increase profits, their implementation is quite a challenge. The primary obstacle in the implementation is the resistance to change by not just the public, but also, and more immediately, the agricultural workers. Switching to new methods requires a greater investment from farmers, which they may be sceptical towards. Additionally, modern technology, like drones and automated machinery, is very expensive and not easily affordable for small - scale farmers (Chadha, 2003). Many farmers are also highly focused on short - term return on investment. As improvements in agriculture caused by these technologies are not immediately apparent, it causes an increase in uncertainty in incorporating the technology.

Another area of concern is the technological literacy required to efficiently use the equipment. Learning how to use these devices, interpreting the data collected from drones and sensors, and maintaining the technology is a task that many farmers may find unnecessarily burdensome. Moreover, the devices may also require internet and power stability which may not be easily accessible in remote agricultural areas. The digital divide between different farmers may also put some farmers at an unfair advantage compared to others, which would significantly reduce the earnings and revenue of those who operate on a smaller scale, or who may not have the capital or resources to get hold of newer technologies for their use.

This can be seen through a detailed study of the agricultural tech development in Africa and India. Sub - Saharan Africa has the largest area of arable uncultivated land in the world. There is very limited internet access, with less than 30% of adults in rural areas having access (Jones, 2005). Moreover, 70% of the farmers are smallholders and do not have sufficient funds to incorporate technology into their day - to - day agricultural processes (Jones, 2005). Similarly, in India, the farm mechanisation level is still only about 40 - 45%, when it could be a lot higher (Panning, Kulkarni, 2011). As 86% of farmers have less than two hectares of land, implementation of new technology becomes progressively more and more difficult.

We may also view this from Roger's Theory of Diffusion of Innovation, which states that when an innovation comes into the market, five stages are evident in the adoption process: knowledge, persuasion, decision, implementation and confirmation (Halton, 2023). This theory can be beneficial in promoting technology among farmers. According to the theory, farmers can be classified in the 'laggard' group of

types of adopters. These people are among the last to use an innovation, because of their risk - averse nature. They only adopt the technology once sufficient acclaim for it is provided. It is essential to provide them with adequate support and guidance to help them understand how technology may be helpful.

Aside from more immediate, in - farm implementation of the use of new strategies and technologies, it is up to policymakers to ensure that advantageous installation of technology in agricultural settings is achieved. Investments in research and development within the agricultural sphere must be increased on priority (Tripp, 2001). Standardised technology may not be helpful in the long run and hence farmer - specific technologies must be developed to account for all kinds of farmers. Training programs must be held regularly to increase awareness about new products and to enhance the farmer's technical skills. During the primary stages, governments can increase the utility of technology by initially introducing low - cost equipment, by offering financial aid and by presenting assistance in case of unanticipated or slow results. Infrastructural development and digital connectivity must also be focused on to maximise agro - tech gains. Regulatory frameworks, and collaborative partnerships between the producers, the farmers and the government will help increase trust and provide assurance to farmers, which would lead to a more productive and forward - looking approach to agriculture. This, however, can only be achieved once farmers make a decisive step to leave behind farming traditionalism and look to newer, more efficient technologies.

4. Conclusion

From the green revolution to now, India has come a long way in agricultural development. It is the largest producer and exporter of many agricultural goods, and has hence become a global giant. India has also been seen to be constantly working towards green and climate friendly agricultural practices, not only for the betterment of its own agricultural industries, but also to ensure better profits and yield that are sure to benefit farmers at an individual scale. From the days of the Green revolution, wherein farmers moved from manual ploughing to tractor technology and the use of HYV seeds, the Indian agricultural industry has surely come of age. As evident in the cases looked at above, progress and change, especially in one of the country's fastest - growing industries, is bound to take time, effort, and a certain amount of persuasion. However, it is safe to say that as the needs of the farmers and people of the country change, so will the methods and technologies used to meet said needs. As these needs evolve, so will these methods and technologies - ensuring a lasting cycle of change that may reap the industry very fruitful benefits.

India's consistency in promoting small - holder farms, adaptation to climate change, and propagation of sustainable agriculture is an epitome of determination and resilience. The steps India has taken towards bettering its agricultural industry, while also keeping a mind for climate resilience and sustainability are efforts that the world may look upon for inspiration. The shifting of the green technology movement towards rural areas from urban areas is a strategy that many countries have decided to implement in their own sustainability plans (Farooq, Ishaq, Shah & Karim, 2010). As technology continues to evolve, we can expect more advanced applications that will further help in meeting future requirements, both at a domestic and international scale. All stakeholders involved in the betterment of the agricultural industry must continue to work cooperatively to ensure similar, if not better results in the future. India's improvement is inspiring, and we look forward to seeing what is to come.

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